Texture Difference Perception between Different Halftone Algorithms

Phichit Kajondecha, Hongmei Cheng and Yasushi Hoshino, Nippon Institute of Technology, Miyashiro, Saitama, Japan

Abstract

Characterization of combination of different halftone algorithm is important for assess image halftone quality. A number of researches attempt to develop halftoning algorithm in order to improve halftone image quality. A main factor that influences the combination of AM and FM halftone transformation is the texture difference emerging in the gray level between AM and FM area. The paper purposes to investigate the false texture difference occurred in AM/FM halftone transformation by subjective evaluation. The relationships between the transformations of difference halftone algorithm and texture difference perception are discussed.

Introduction

Digital halftoning is an essential technique to reducing the number or gray levels or colors in a continuous image to binary level while maintaining the image quality of continuous image. A halftone image is typically displayed on media that cannot reproduce continuous image. Since digital halftoning produce binary value, many algorithms have been studied and proposed to producing the high-quality halftone image. The two most common conventional algorithms of digital halftoning are Amplitude Modulated (AM) and Frequency Modulated (FM). Cluster dot dithering algorithms is an example of a technique for generating an AM halftone structure. In the AM halftone structure, the size of the dots is variable while their spacing is constant. The single dot within the halftone cell becomes larger when the tone value becomes darker as well as smaller when the tone value becomes lighter. Among FM halftone structures, error diffusion, which was invented in the 1970 by Floyd and Steninberg, is an adaptive algorithm. In the FM technique, contrary to the AM technique, the size of the dots is kept constant while the halftone space is variable. The number of dots within the halftone cell increases when the tone value becomes darker as well as decreases when the tone value becomes lighter. The advantages and drawbacks of each digital halftoning algorithms are the challenges to develop the appropriated algorithms to produce the high quality halftone.

The number of studying on combination of AM/FM technique attempts to develop the digital halftoning algorithm by using the advantages of AM and FM algorithms. AM algorithms are especially useable in the mid-tone because dot gain is lower then when a FM algorithm is used there. FM algorithm, on the other hand, performs very well in the highlights where the optimized dot positioning and the minimum dot size allow for an appropriated match to the algorithm limitations of the printing technology. The result of study indicates that the combination of AM/FM halftoning make it particularly suitable for conventional printing. Although the combination of AM/FM halftoning use the advantages of AM and FM algorithm, it raises an issue of texture difference between midtone and highlight area. Figure 1 shows the texture difference of halftone image occurred in the combination of AM/FM halftoning. Texture difference in an image are important factor for evaluate the image quality because our image perception and recognitions depend on the texture difference in that image. Texture difference is the boundary between different surfaces. In order to achieve high-quality digital halftoning, the characteristic of texture difference of an image is considered important to be reducing. One way to understand and evaluate image quality is use of a Human Visual System (HVS).

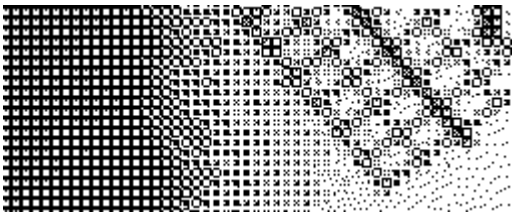


Figure 1. show texture difference in the combination of AM/FM halftoning.

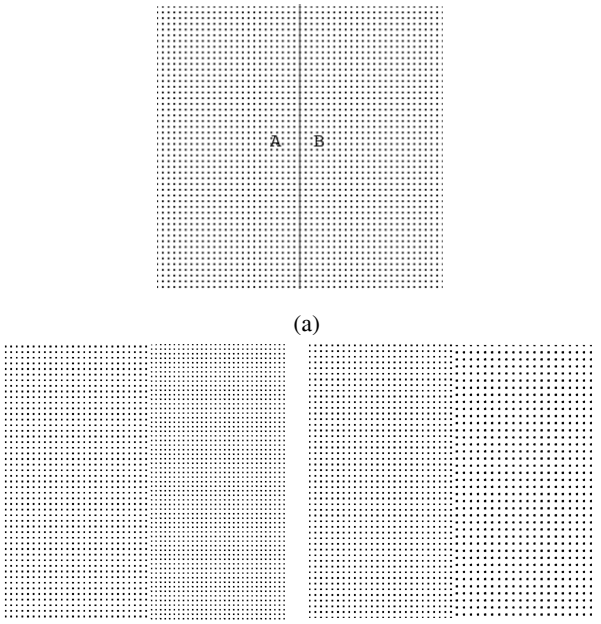
This paper aims at investigating the perceptibility of texture difference of halftone image with difference halftone algorithms. The halftone frequency and observation distance will be considered as the main factors in the experiment. The result of experiment will be used as the basis component of developing the appropriated digital halftoning algorithm to reducing the texture difference and improve the quality of halftone image.

Experiment

The effect of texture difference perception in halftone frequency has been investigated. The result of experiment is used to generate a new halftone algorithm that aims to reducing the texture difference in halftone image.

Texture Difference Perception in Halftone Frequency

First, the texture difference perception on the same image density for the same halftone algorithm is considered by focusing on the changing of halftone frequency. As shown in Figure 2 (a) original halftone image, a type of image was produced: (A) the original image with 1 cycle/mm and (B) the simulated halftone image with different cycle/mm step. Figure 2(b) is an example of halftone image with increasing frequency step at 1.2 cycle/mm as well as Figure 2(c) shows the example of halftone image with decreasing frequency step at 0.8 cycle/mm.



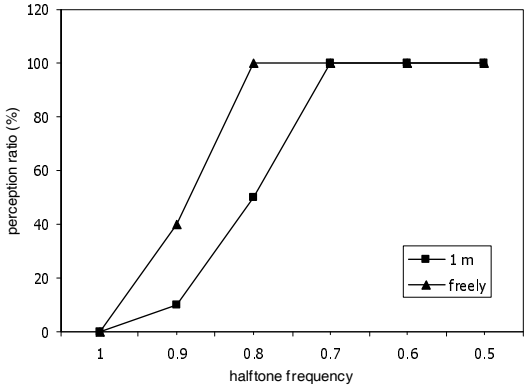
(a)

(b) (c)

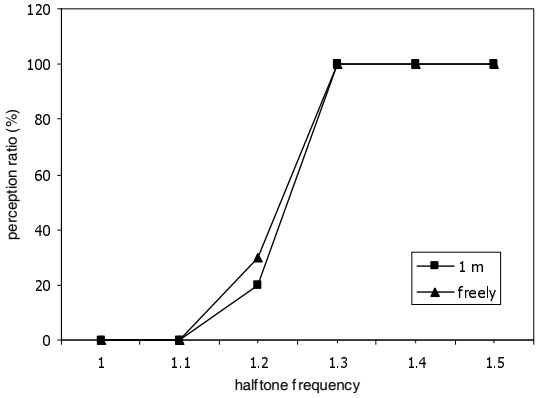
Figure 2. Example halftone difference frequency (a) the original halftone image (b) sample halftone image increasing frequency (c) sample halftone image decreasing frequency

Result of experiment

The results of experiment shows the perception ability of 10 testees at 2 observation distance; 1 m and freely distance at under an illumination of a typical office environment with fluorescent lamps. Figure 3 shows the perception ratio against different halftone frequency. It shows that human detects the texture difference of halftone image at freely observation distance when halftone frequency with 0.9 halftone frequency. Although the result of 1m observation distance shows that human detects the texture difference when halftone frequency with 1.1 halftone frequency, the perception ratio is less than the result of freely observation distance. The result of 1m observation distance when increased halftone frequency shows in the same way. It indicates that human tends to detect texture difference decreasingly when the observation distance increases.



(a)



(b)

Figure 3. Perception ratio against halftone frequency (a) at increased halftone frequency and (b) at decreased halftone frequency.

The texture difference of halftone image with difference halftone frequency can be explained by Discrete Fourier Transform (DFT) curve. Figure 4 shows the DFT of halftone frequencies on the horizontal axis of the scale of cycle/mm. It shows that the halftone frequency affects the peak of halftone dot strength. The peak of halftone dot strength tends to shift right side from original when the halftone frequency increases. It implies that human detects the texture difference of image when the difference of halftone frequency increases.

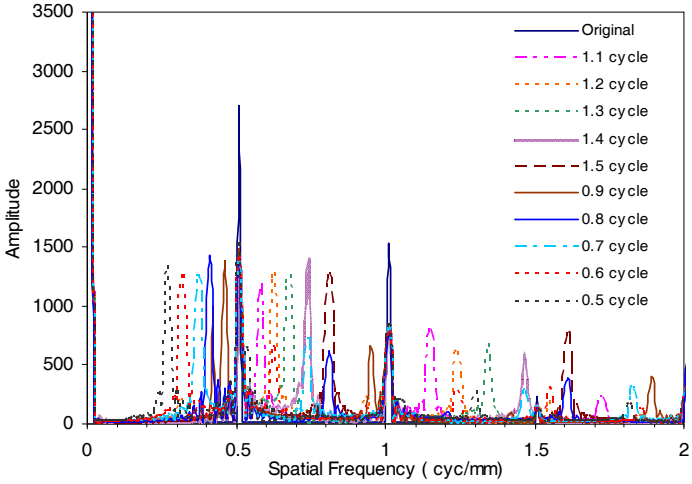


Figure 4. DFT curve of halftone frequencies.

The Proposal of Halftone Technique

We generated a new halftone algorithm according to the result of texture difference perception. The minimum halftone dot size has been fixed while the halftone frequency is variable. The halftone image generated by the halftone technique as above is illustrated as Figure 5. Figure 6 show the DFT of halftone frequency for the proposed halftone technique to evaluate the effectiveness of the algorithm. The result shows that the peak of halftone dot strength becomes discrete in the same way. Since the position of peaks of halftone dot changes gradually, human cannot detect texture

difference occurred in the image. It indicates that the new halftone technique reduces the texture difference of halftone image.

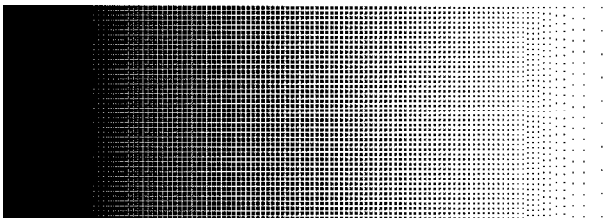


Figure 5. Proposal of halftone technique.

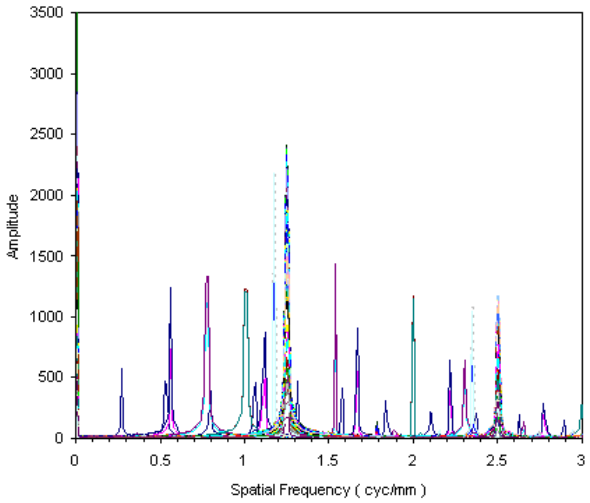
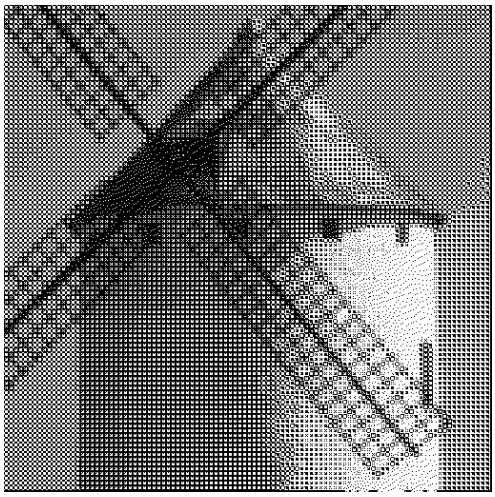


Figure 6. DFT curve of proposal halftone technique

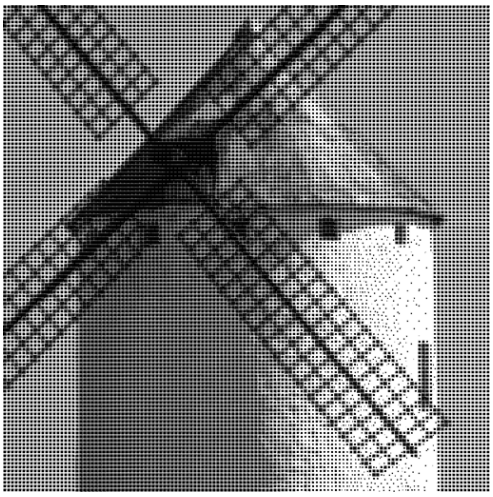
Figure 7 show the comparison the halftone image between AM halftone technique, FM halftone technique, general AM/FM combination halftone technique and our proposed halftone technique. The texture difference can be reduced by using the proposed halftone technique. The halftone image looks smoothly. Human eye can not detect the texture difference between midtones and highlight area.

(a)

(b)



(c)



(d)

Figure 7. halftone image(a) AM halftone technique (b) FM halftone technique (c) generated by general AM/FM combination halftone technique (d) generated by proposed halftone technique

Results and Discussions

The paper investigated the perceptibility of texture difference of halftone image with difference halftone algorithms and proposed the halftone technique to eliminate texture difference of halftone image. The halftone frequency and observation distance are considered as the main factors in the experiment. The result indicates that the observation distance and the difference of halftone frequency affects texture difference perception. Human percepts texture difference decreasingly when the observation distance increases. In case of considering the effect of halftone frequency, human percepts texture difference increasingly when the difference of halftone frequencies increases. The result of proposed halftone technique indicates that it has possibility of reduces texture difference of a halftone image.

References

1) S. Gooran and B. Kruse "Hybrid Halftoning" ITN Research report, LITH-ITN-R-2004-1.
2) P. Kajondecha, H. Cheng, and Y. Hoshino "Human Perception of Contour in Half-Toned Density Step Image." Imaging Sci. Technol. 51 (5), 402 (2007).
3) Henry R. Kang : "Digital COLOR Halftoing", SPIE/IEEE SERIES ON IMAGING SCIENCE & ENGINEERING, pp. 2-8(1999)
4) Shigeru Kitakubo and Yasushi Hoshino : Some Characteristics on Human visual Sensitivity for spatial frequency of Digital halftone Images, Proc.NIP21, pp. 118-121(2005).
5) L. L. Daniel, and R. A. Gonzalo, Modern Digital Halftoning, (CRC Press, New York, 2001) p 42.
6) W. Lei, P. Kajondecha, H. Cheng, and Y. Hoshino "Study of a perception condition of half-toned density change of sin wave" Proc. I.I.E.E.J., Media Computer Conference 2006
7) P. Kajondecha, H. Cheng, and Y. Hoshino, "Perception of contour between different halftone algorithms." Proc.PPIC'08 Pan-Pacific Imaging Conference, Tokyo,2008

Author Biography

Phichit Kajondecha is a PhD. student in Hoshino Laboratory, Systems Engineering Department, Nippon Institute of Technology. He had learned computer and information technology from King Mongkut's University of Technology thonburi (Thailand) in background. His research interest includes halftone, Color and Image processing